TITLE
ASP Conference Series, Vol. **VOLUME***, **YEAR OF PUBLICATION**
NAMES OF EDITORS

Satellites of Isolated Elliptical Galaxies

R.M. Smith

School of Physics and Astronomy, Cardiff University, P.O. Box 913, Cardiff, CF24 3YB, Wales

V.J. Martinez

Astronomical Observatory. University of Valencia, P.O. Box 22085, E-46071 Valencia, Spain

Abstract. Using well-defined selection criteria applied to the LEDA galaxy catalogue we have derived a sample of elliptical galaxies that can be classified as isolated. From this we have investigated the neighbourhood of these galaxies to determine the frequency and radial distribution of faint galaxies around them and hence derive an estimate of their surrounding satellite population. The results are compared and contrasted to the satellite population around isolated spiral galaxies.

1. Introduction

The morphology-density relationship for galaxies, first investigated by Dressler (1980), indicates that ellipticals preferentially occur in regions of high galactic density, whilst spiral galaxies dominate in the 'field'. Together with the properties of 'typical' elliptical galaxies, with the domination of the stellar light by an old, red, population and little evidence of recent star formation or mergers, this lends support to the hypothesis that such galaxies are formed from mergers early on in the evolution of the Universe. Theoretical simulations also provide clues that elliptical galaxies primarily form at early epochs. However, the simulations do suggest that ellipticals in low density regions form over a much longer timescale and are therefore likely to show evidence of recent mergers or star formation activity (e.g. Baugh et al. 1996). Recent studies of the properties of 'isolated' elliptical galaxies have been inconclusive, with some showing evidence of a young stellar population (e.g. Kuntschner et al. 2002) whilst others indicate no recent merger events (e.g. Silva and Bothun 1998). A major problem in comparing the results of these investigations is the varying definition of an isolated galaxy. What is required is the objective selection of a sample of galaxies in low density environments for direct comparison with both those galaxies in groups and clusters and also theoretical models. From such a sample we can not only investigate further the properties of the galaxies themselves but also undertake a detailed study of their local environment, which simulations suggest should provide strong clues as to the formation history of the galaxy.

2. Sample Selection

The determination of an objective definition of 'isolated' is difficult. In their study of isolated spiral galaxies, Zaritsky et al. (1993, 1997, hereafter ZSFW) used two criteria to select their sample, To be isolated, the magnitude difference between a neighbour and the 'parent' must be greater than 0.7mag for galaxies within a projected distance of 1Mpc, or greater than 2.2mag within 500kpc. With a lack of detected satellites at distances greater than 500kpc there was *a posteriori* support for the use of these criteria to select isolated galaxies. We therefore use their criteria as a basis for the selection of a sample of isolated ellipticals.

The absolute magnitude and surface brightness limits reached by the ZSFW survey were such that it did not enter the dwarf regime. At present there are major uncertainties in our knowledge of the faint end of the Galaxy Luminosity Function, with some evidence of an environmental dependence (e.g. Driver et al. 1999, Davies et al., this conference). With the current uncertainty in the LF shape at the faint end, we will define a sample of galaxies that are isolated from other bright galaxies ($\mathrm{M_B} < -17$).

The availability of catalogues of large numbers of galaxies now makes it viable to investigate the environmental properties of galaxies and hence select a sample of objects that satisfy certain isolation criteria. The LEDA and NED catalogues are two of the most widely used catalogues. Here we use the LEDA catalogue which now contains well over a million galaxies from a wide variety of sources. This catalogue is not complete to any given magnitude but here we are interested in defining a sample of isolated galaxies that match certain criteria and do not investigate the statistics of such a sample. Firstly, the sample of ellipticals was defined using the following criteria:- (i) Redshift less than $10000 kms^{-1}$ – to ensure the sample is almost complete, (ii) Absolute magnitude $\mathrm{M_B} \leq 19$ – to ensure galaxies are 'normal', any satellites found are brighter than the possible turn-up in the LF and that the sample is again approximately complete, (iii) Galactic latitude $> |25^\circ|$ and (iv) Morphological type $\mathrm{t} < -4$.

Using these criteria produced a sample of 940 ellipticals, to which the ZSFW criteria for 'isolatedness' were applied. Again the LEDA database was used to search for neighbours around the central elliptical. In this study no redshift information was used to select or reject possible isolated galaxies. The criteria are therefore much stricter than used in other studies but ensures that the galaxies are truly isolated. However, it rules out any statistical study of the frequency of isolated galaxies. Out of the 940 elliptical galaxies in the sample, 32 satisfied the ZSFW criteria. All of these galaxies were cross-checked with the NED catalogue to ensure they were isolated from bright galaxies in that catalogue.

3. The Satellite Population

Previous studies have concentrated on the properties of the central elliptical yet from the morphology-density relationship it is clear that the environment must play a very significant part in the evolution of the galaxy. The surrounding galaxy population also gives strong clues to the formation history of the galaxies. Although the objects selected here are isolated from bright galaxies they may be

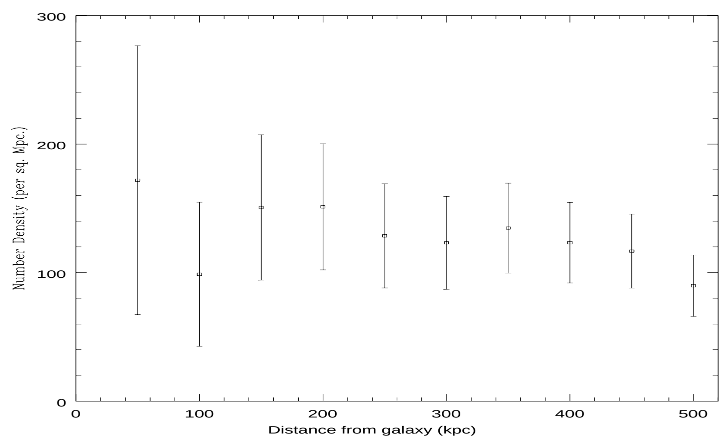

Figure 1. Radial profile of galaxies surrounding, on average, isolated ellipticals

surrounded by a halo of fainter, dwarf, galaxies. To investigate this possibility we have employed a technique similar to that of Holmberg (1969) and Lorrimer et al. (1994, hereafter LFSWZ). Using the data publicly available from the APM plate-scanning machine, we have selected all galaxies in the field of the parent detected on the UK and Palomar Schmidt sky survey plates.. Due to the clustering properties of galaxies, any statistical excess over that of the surrounding area is likely to be due to surrounding dwarfs. An absolute magnitude limit of $M_{Bj} = -14.6$ for the surrounding galaxy population (assuming they are all at the redshift of the parent) and a redshift limit of $6500 kms^{-1}$ for the primary was applied to ensure that the APM scans were reasonably complete for high surface brightness objects (it is well-known that at low surface-brightnesses the catalogue is incomplete). It also ensures that any surrounding galaxies will be dwarfs. Brighter than $M_B = -16.8$ the sample of dwarfs is incomplete due to the isolation criteria used to select the parent sample. A total of 10 galaxies in the sample of 32 had APM data suitable for this study.

Due to the large range of redshifts of the parent galaxies the background population varies widely. In this study we have stacked the profiles of all 10 of the galaxies to obtain a 'mean' profile. This is shown in Figure 1. It is clear that there is a significant excess of dwarf galaxies within 500kpc. To obtain an estimate of the dwarf population requires subtraction of the contaminating background population. With ZFSW finding very few satellites beyond 500kpc we use the outer values of the radial profile as an estimate of the background. Fitting a power law to the resulting background-subtracted galaxy counts gives a power-law slope of -0.6 ± 0.2. This is similar to the slope found for late-type galaxy satellites by LFSWZ but less steep than that found by them for early-type galaxies. However, they found a weak dependence of the slope on the satellite luminosity, with fainter galaxies having a flatter slope. Extrapolating

their results to the magnitude limits reached in this study, there is good agreement with the value presented here. They did not find such a dependence for late-type galaxies.

There are 45 ± 15 dwarfs within 500kpc of the primary down to the limiting magnitude of 14.6 and 19 ± 6 with $-16 < M_B < -15$. Brighter than -16 the number of satellites agrees with the values of LFSWZ. Comparing the number of faint dwarfs to the values for brighter satellites implies a steep luminosity function ($\alpha \sim -1.8$), in approximate agreement with that found for poor clusters (e.g. Driver et al. 1998) and also the value derived by Morgan et al. (1998) for isolated spirals. LFSWZ also proposed a steep luminosity funtion around early-type galaxies as an explanation for the differing clustering length for bright and faint neighbours. This lends some support to the CDM model of hierarchical structure formation (e.g. White and Frenk 1991), where there should be an abundance of small dark matter halos. However, the field luminosity function has a slope of -1.2 (e.g. Norberg et al. 2002) suggesting that dwarf galaxies are not the dominant population everywhere. In addition, comparison of the radial density profiles for the individual galaxies shows much variation, with some galaxies having a very concentrated dwarf population, some more extended and some have no surrounding dwarfs, suggesting that the luminosity function is variable. However, the errors are large and thus a more detailed interpretation of the galaxy-to-galaxy variations awaits a deeper CCD survey of the fields of these galaxies, together with a redshift survey to determine the satellite population.

References

Baugh C.M., Cole S., Frenk C.S., 1996, MNRAS, 283, 1361

Dressler A., 1980, ApJ, 236, 351

Driver S.P., Couch W.J., Phillipps S., 1998, MNRAS, 301, 369

Holmberg E., 1969, Ark. Astron., 5, 305

Kuntschner H., Smith R.J., Colless M., Davies R.L., Kaldare R., Vazdekis A., 2002, MNRAS, 337, 172

Lorrimer S.J., Frenk C.S., Smith R.M., White S.D.M., Zaritsky D., 1994, MNRAS, 269, 696

Morgan I., Smith R.M., Phillipps S., 1998, MNRAS, 295, 99

Norberg P., Cole S., Baugh C.M., Frenk C.S., Baldry I., Bland-Hawthorn J., Bridges T., Cannon R. et al., 2002, MNRAS, 336, 907

Silva D.R., Bothun G.D., 1998, AJ, 116, 85

White S.D.M., Frenk C.S., 1991, ApJ, 379, 52

Zaritsky D., Smith R.M., Frenk C.S., White S.D.M., 1993, ApJ, 405, 464

Zaritsky D., Smith R.M., Frenk C.S., White S.D.M., 1997, ApJ, 478, 39